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Demonstration of Co-generation Technology in Alberta

Projects supported in part
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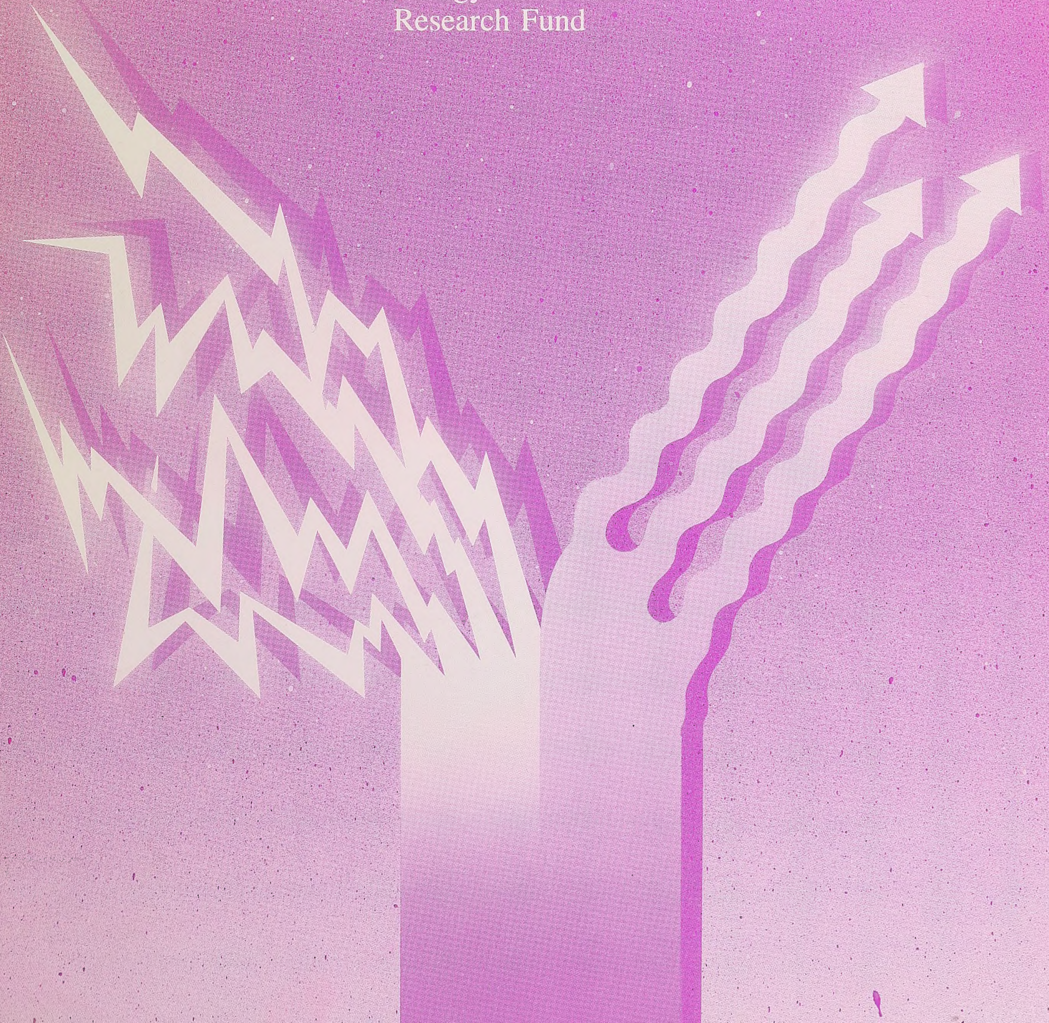
Research Fund



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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Research and Technology Branch of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 12.

Demonstration of Co-generation Technology in Alberta

Co-generation, the simultaneous production of electric and thermal energy from a single fuel source, is capable of saving a significant portion of the fuel required to produce each energy form separately. It is also an energy conservation method that can be used in many commercial and institutional buildings. With the advent of reliable, reasonably priced generators, many building owners in the United States have installed co-generation systems to produce electricity and heat on-site for a variety of uses. This growing interest in co-generation prompted the Alberta/Canada Energy Resources Research Fund (A/CERRF) Committee to support four investigations of current technologies to determine their suitability for Alberta conditions. They are described here.

Edmonton District Heating Study

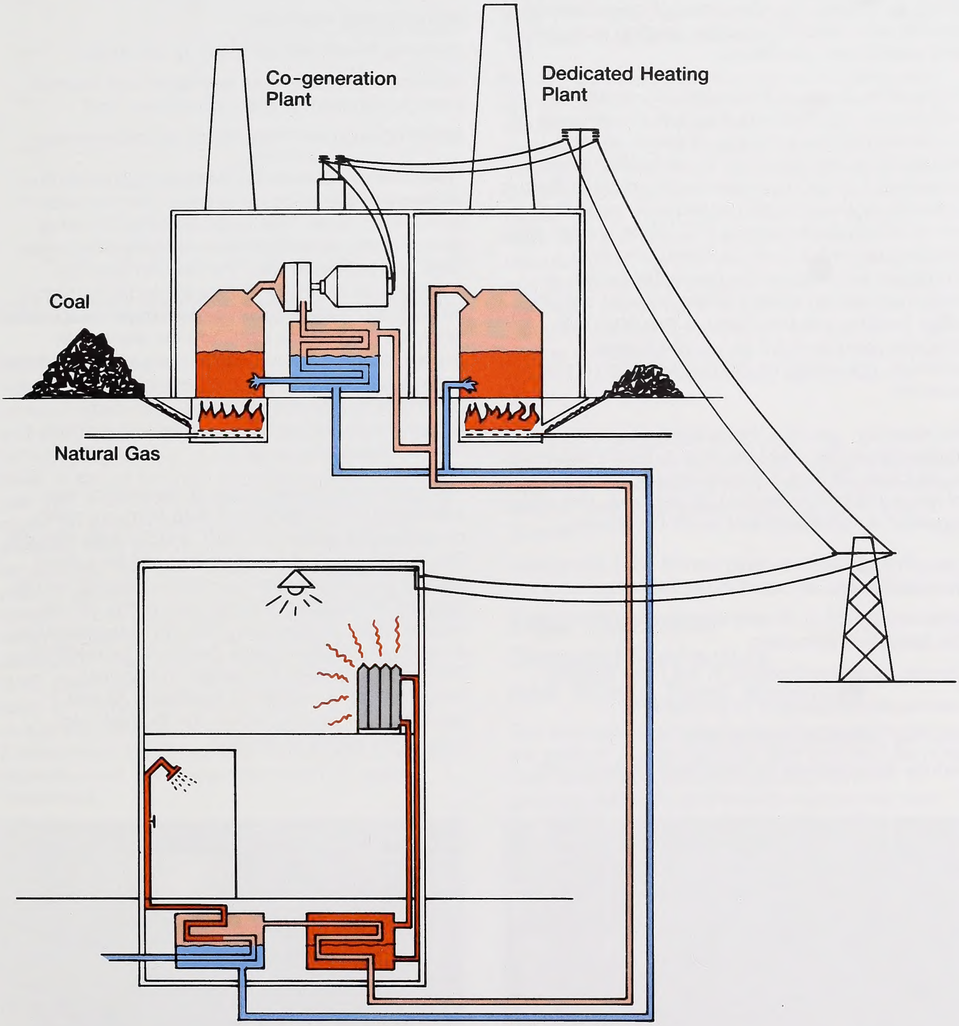
As early as 1978/1979, investigations were launched to determine the technical and economic feasibility of co-generation systems in Alberta. Using financial support from A/CERRF and Edmonton Power (the electricity-generating arm of the City of Edmonton), an engineering consortium (Stanley-Ekono) considered the viability of recovering heat from one or more existing generators at Edmonton's Rossdale Generating Plant and using it in a district heating scheme. The concept was based on experience in Helsinki, Finland, where a district heating system using a combination of co-generation and dedicated heating plants supplied more than 70 per cent of the city's heating requirements. This is expected to reach 90 per cent in 1990. Furthermore, this and other Finnish district heating systems had thermal efficiencies of 85 per cent. This compares with approximately 60 per cent thermal efficiency for buildings that are heated individually, and electricity is generated by a separate process.

In Edmonton, which is approximately comparable to Helsinki in population and climate, it was suggested that part of the downtown area could be served by the proposed district heating scheme. This area contained more than 40 commercial, institutional and apartment buildings, and all used natural gas heating. Calculation of heating requirements for existing buildings and those anticipated to be built revealed that a peak demand of 106 MW could be expected 10 years after connection to a district heating system. It was found that this heating energy could be supplied easily if one of 10 turbine generators at the Rossdale Generating Plant were converted to an extraction-condensing turbine. A 100 MW hot water boiler would be needed as well. A second turbine generator could be converted, or a second boiler could be added to the first turbine, if the maximum heat demand in the service area exceeded the heat production capacity of the first turbine. In either case, a two-pipe hot water distribution system was proposed to connect the generating plant to the serviced buildings.

The costs of installing and operating the system were calculated for both the original service area and a much-expanded area of downtown Edmonton. The capital costs of a co-generation system for the original service area would be approximately $10.3 million, expressed in 1979 dollars. For the expanded service area, capital costs were expected to range from $17.7 to $21.7 million, depending on the equipment installed at the generating station. This was expected to produce an acceptable return on investment and it was concluded the district heating scheme was financially feasible under a variety of economic and operating conditions. Such a system would have some environmental benefits, too, caused by less natural gas consumption and fewer discharges of warm water into the North Saskatchewan River.

The City of Edmonton decided not to proceed with the scheme, but a second study (not funded by A/CERRF) was initiated by Edmonton Power in 1983 to determine the feasibility of supplying heat to the downtown core from the Genesee electricity-generating station then under construction 50 km southwest of the city. This investigation also concluded that a district heating system using heat supplied by co-generators at Genesee would be both technically and economically feasible.

Principles of District Heating



(Source: *Edmonton District Heating Study: Financial Feasibility,* Stanley-Ekono, February 1980)

Co-generation Assessment Study

In this project, carried out between 1985 and 1988 by the Southern Alberta Institute of Technology (SAIT) in Calgary, the economics of co-generation in Alberta were determined under existing economic and capital cost conditions.

In the initial phase of the project, co-generation technology was reviewed, the cost effectiveness of co-generation systems was determined, and regulatory issues related to co-generation were evaluated. Economic assessments indicated there is potential for co-generation systems in operations where electricity demand is 500 kW or greater and the thermal load is both consistent and high. Computer simulations of a residential duplex, a restaurant and an office building showed only the office building was promising. It indicated that payback periods of 4.6 to 7.1 years were probable, depending on the co-generation equipment selected.

For example, use of a Waukesha 1 200 rpm engine/generator could result in a discounted years to payback (DYP) of 4.6 years and an internal rate of return (IRR) of more than 33 per cent. This was regarded as an investment worth considering.

Use of co-generators could benefit utility companies in several ways, as noted in the following:

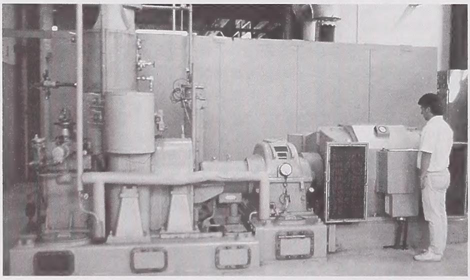
- allow construction of central generating plants to be delayed or cancelled;
- provide increased flexibility in the utility system;
- reduce excess capacity in the system;
- improve utility load control; and
- reduce requirements for expensive peaking units.

Owners of co-generation equipment could benefit by:

- reducing their total energy consumption and costs;
- gaining greater control over energy costs;
- selling excess electricity;
- obtaining investment and energy tax credits;
- receiving exemption from regulatory and financial controls imposed on utility companies; and
- achieving improved reliability of electrical services.

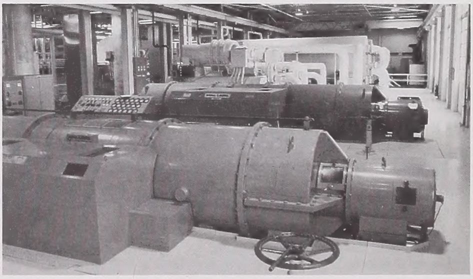
Three limitations were identified that could hamper widespread use of co-generators. The first was economy of scale. This could be offset by rising energy costs, as well as the availability of modular units and increased use. The second was the operating environment. If excess electricity cannot be sold, the co-generation system must be operated to match the thermal load, and the owner can expect to purchase substantial amounts of electrical energy, especially during low thermal periods. The last limitation was the attitude of local utility companies to the use of co-generation systems in their service areas.

The preliminary review stage of the project was followed by the collection of data from operating co-generation systems at SAIT and Foothills Hospital. The system used at the hospital provides base loading and shaves peak electrical demand, and is capable of providing 100 per cent of the on-site requirements, if necessary. The SAIT co-generator is used only to shave peak demands for electricity. The data confirmed the earlier finding that co-generation is marginally feasible in Alberta if used in larger facilities where the thermal load follows the electrical demand.



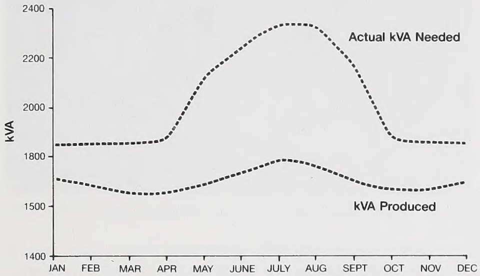
The 150 kW steam turbine at the Southern Alberta Institute of Technology was operated under co-generation conditions at various heat and electricity loads.

(Photo courtesy of Southern Alberta Institute of Technology)



The operation of co-generators at Foothills Hospital in Calgary was studied by researchers at the Southern Alberta Institute of Technology.

Simulated Performance of a Waukesha 5900G Engine Generator to Supply Thermal and Electrical Energy for An Office Building



(Source: *Co-generation Assessment Study*, Vardabasso, M. and T. Grusendorf, Southern Alberta Institute of Technology, September 1986)

In the third phase of this project, the 150 kW Gas Turbine Total Energy Plant at SAIT was operated under co-generation conditions at various heat and electricity loads. The plant incorporates a gas turbine generator set, a waste heat recovery boiler, a lithium bromide absorption chiller and a gas-fired boiler. Complete energy balances, energy costs, generation cost analyses and economic analyses were performed for situations in which an electrical load was created by connecting the plant in parallel with the SAIT electrical supply system. These calculations also applied to occasions when generated steam was supplied to the absorption chiller and the heating system used at SAIT. Data indicated that the system could be used economically in Alberta when the thermal output was used to drive an absorption chiller. It was stated that the greater the amount of chilling capacity used, the greater the return on initial investment.

An essential requirement of a co-generation plant is its ability to convert efficiently the internal energy of a fuel into heat and electricity. This energy conversion occurs through the various components of the plant. They are:

- engine (sometimes called "prime mover");
- electric generator;
- heat recovery system;
- controls and instrumentation;
- transmission and distribution network; and
- connections to the user.

In choosing the principal component, the prime mover, several factors must be considered. One of the most important is the Heat-to-Power Ratio (HPR), which expresses the co-generation plant's output ratio of heat to power. It is generally accepted that the output must be modulated to match needs. Although various methods for doing this were considered, it was found that the most flexible method of HPR modulation appears to be the Cheng Cycle. This involves injecting excess steam from the boiler into the gas turbine, where it is used to generate electricity.

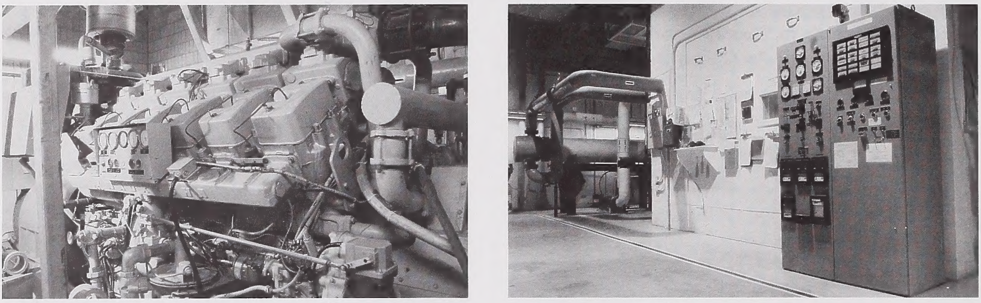
It was suggested that stand-alone co-generation plants that are completely independent of existing electricity grids were feasible in Alberta. A list was prepared of types of industries and building services that were most amenable to stand-alone co-generation systems. This included plastics and rubber plants, glass producers, meat, poultry, feed, flour and cereal operations, clothing manufacturers, various wood-working operations and plants handling crude petroleum and natural gas. Also, offices up to 4 620 m^2 (49 729 sq. ft.), shopping centres up to 465 m^2 (5 005 sq. ft.), as well as universities, colleges, hospitals and other health care facilities were likely candidates for stand-alone systems.

The SAIT investigators concluded that co-generation was both a feasible and environmentally acceptable method of generating energy, and more should be done to encourage wider use of co-generation in Alberta.

Peak Electrical Demand Reduction and Waste Heat Recovery

The emergency generators in many large buildings are seldom, if ever, used for their intended purpose. They could be employed regularly, however, to generate electricity and thereby reduce the peak demand for power supplied by local utility companies. Also, the heat produced by these generators could be recovered, thus reducing the purchased fuel requirements of buildings.

With this as a background, Cheriton Engineering Inc. of Edmonton studied the operation of an existing 1 MW natural gas-powered co-generator at the University of Lethbridge. This unit, purchased in 1980, was used to "shave" peak electrical demand, thus reducing the power demand charges levied by the utility company. Initially, peak shaving was confined to the summer months to offset loads created by the operation of chillers. However, demand for electricity has increased since 1980, causing the co-generator to be used year-round for peak shaving. When the co-generator operated, heat was recovered from the engine jacket water



At the University of Lethbridge, the operation of a 1 MW co-generator (left) and its sophisticated control system (right) was studied by Cheriton Engineering Inc.

and used to preheat the campus heating water before it was returned to the main boilers. Typically, the co-generator was operated approximately 800 hours each year and was available as an emergency generator the rest of the time.

A Honeywell Delta 5200 Central Monitoring System, connected to the appropriate sensors, was used to record critical system temperatures. Other monitored or calculated data included: natural gas consumption, recovered energy rate, electrical power generation rate, power factor, energy demand and generated electricity. Operating costs and savings were also calculated.

In evaluating the ability of the co-generator to reduce energy costs, the consultants recognized that the rate structure set by utility companies for large energy consumers comprises two elements. They are:

- Energy Charge, based on the actual units of consumed energy; and
- Demand Charge, which is based on the peak electrical demand by the consumer over a certain period. The demand charge is applied to the entire period even if the peak occurred for a short duration.

From the monitored data pertaining to the energy charge, it was apparent that it was less expensive to purchase electricity from the local utility company than generate it at power loadings of less than 900 kW. Above this figure, cost savings of only $2 or $3 an hour could be expected. This is subject to the electricity rates charged at a particular location, which vary throughout Alberta.

Savings associated with peak shaving were significant. For example, when the co-generator was operated at full output, cost savings of $60 an hour were possible. At lower output, savings were proportionally smaller. At full output, savings were equivalent to a payback period of 7.1 years. This assumed capital costs of $400 000 for the co-generator.

The benefits of heat recovery were less significant. Although energy recovered from the engine jacket represented 40 per cent of the net amount of electrical and thermal energy recovered from the system, the associated cost savings were only 6.6 per cent of the total. Therefore, for this installation, heat recovery could not be regarded as the primary economic justification for the co-generator. Also, it was found that the average heat recovery efficiency was approximately 15 per cent compared with reported efficiencies of 20 to 25 per cent.

Several possible modifications to the equipment were considered to improve the heat recovery efficiency. Most were regarded as uneconomic because payback periods were seven years or longer. Nonetheless, installation of a differential temperature controller to prevent reverse heating was recommended by the consultants.

Although cost savings associated with heat recovery were only 6.6 per cent of the total, those resulting from peak demand shaving averaged 56.6 per cent and electrical cost savings were 36.8 per cent. The consultants concluded that any decision to purchase a co-generator should be based on peak load shaving and electrical energy savings, whereas heat recovery should be considered only as an added benefit.

The consultants suggested several guidelines that should be followed when the purchase of a co-generator is being considered. These guidelines fall into two categories: electrical considerations and heat recovery considerations.

Electrical Considerations

Within this category, prospective users were advised to consider loads that can be turned off to reduce the peak load. Control equipment that cycles loads is less costly than a co-generator. However, a co-generator can provide backup to other emergency generating equipment or individual transformers in a system.

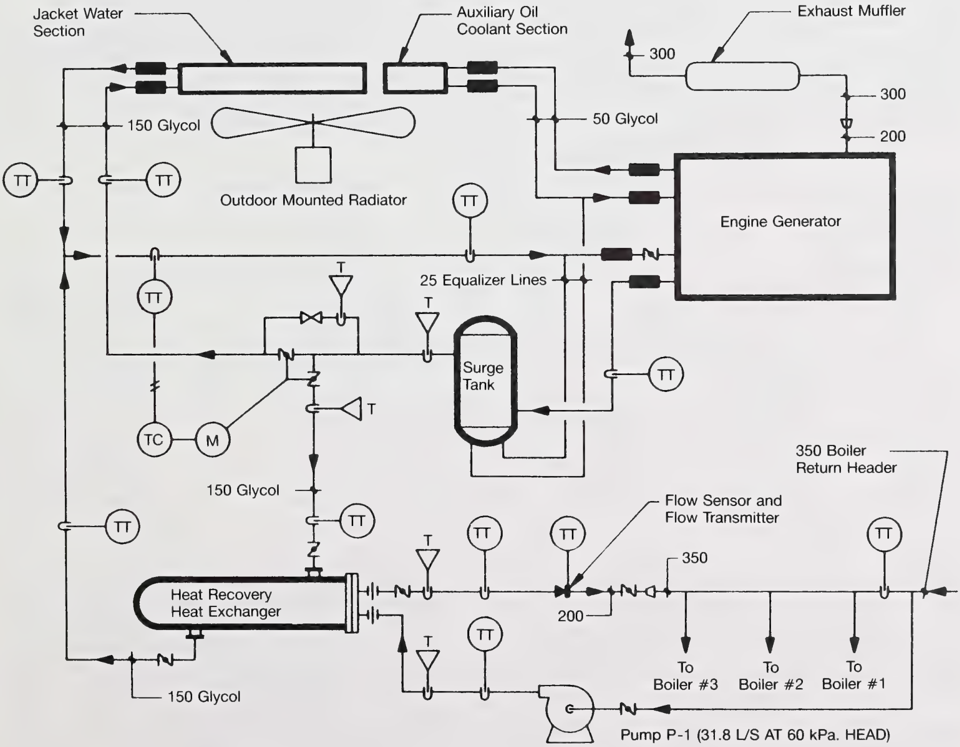
It was also recommended that utility rate structures and load demand profiles be reviewed. Thus, the load profile could be used to determine the expected annual machine operating hours. This will help determine the type of unit required.

It was suggested that utility and electrical code requirements be determined to decide whether parallel generation can be considered. As well, staffing requirements should be determined to confirm extra costs directly related to the installation.

Heat Recovery Considerations

Under heat recovery considerations, a demand must exist for low- to medium-grade heat and it must coincide with generator operation. Because the quantity of recovered heat is directly proportional to the generator operating time, the generator must operate for a reasonable number of hours each year (probably more than 800 hours) to obtain an acceptable payback period. Also, a minimum approach temperature (the difference between the generator jacket coolant temperature and the process fluid return temperature) of 10°C must exist before jacket water heat recovery is contemplated. Otherwise, exhaust gas heat recovery should be considered.

Co-generation System Schematic



(Source: *Peak Electrical Demand Reduction and Waste Heat Recovery Through Co-generation,* Cheriton Engineering Inc., January 1989)

Co-generation Demonstration in Commercial Buildings

There are few natural gas-driven, reciprocating co-generation units in Alberta, and little is known about the operating characteristics and costs of those that do exist. Thus, in 1987, Northwestern Utilities Limited, a natural gas distributor in Edmonton, began a project involving the installation and operation of a co-generation unit in a commercial establishment.

An examination of the gas company's records revealed that approximately 100 commercial and industrial customers were possible candidates for a demonstration project because each was capable of using the heat generated by a co-generator and having an electrical demand exceeding 100 kW during normal hours of operation. Sixty of the initial 100 customers indicated a willingness to participate in the project. Eventually, it was decided to proceed with an installation at one of the commercial laundries operated by the Edmonton firm, Cleaning by Page. Cost projections indicated that a 115 kW co-generator suitable for Page's needs would cost approximately $100 000 and should have a payback period of less than five years. This estimate was based on displacement of electricity costing $12 a gigajoule and production of heat that would be used in the laundry.

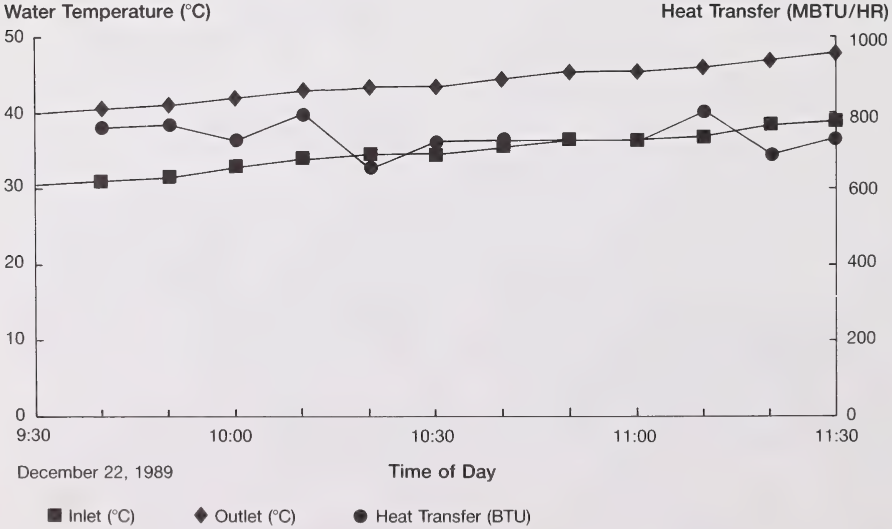
A Waukesha model F-1197, 115 kW co-generation unit was installed in May 1988. It was rated at 136 kVA and had a power factor of 0.845.

Mechanical problems were experienced soon after the unit began operating. Besides expected startup troubles, it became necessary to change the water piping system and to cope with excessive vibration caused by the co-generator. These and other difficulties were not completely corrected until January 1989, causing a delay in initiating the monitoring phase of the project.

The co-generator began operating somewhat steadily in mid-January 1989, but control problems arose and persisted for months. For the January to December 1989 period, the co-generator was available for operation 194 out of 246 days of plant operation. This represents a daily-use rate of 79 per cent.

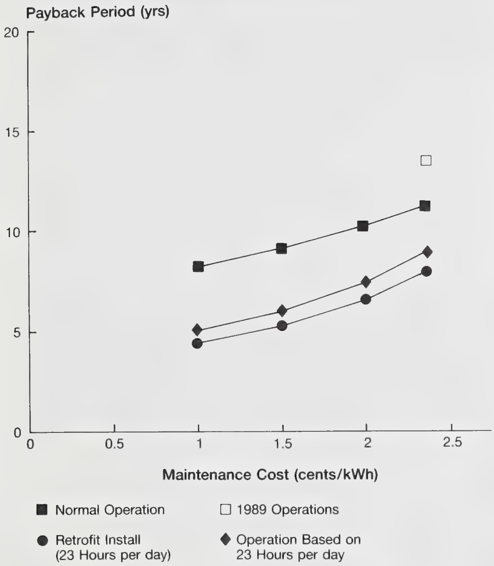
On average, the unit consumed 1.46 GJ/h of natural gas and produced 107.8 kWh of electricity. The overall energy efficiency of the unit was found to be 81.6 per cent, which is within the range (70-82 per cent) for units of this type. The maintenance expenses for the first year of operation were substantially higher than anticipated, averaging $0.0236/kWh versus an initial estimate of $0.005/kWh. The actual costs, therefore, were $2.54 for each hour of operation.

Cleaning by Page
Co-generation Thermal Output

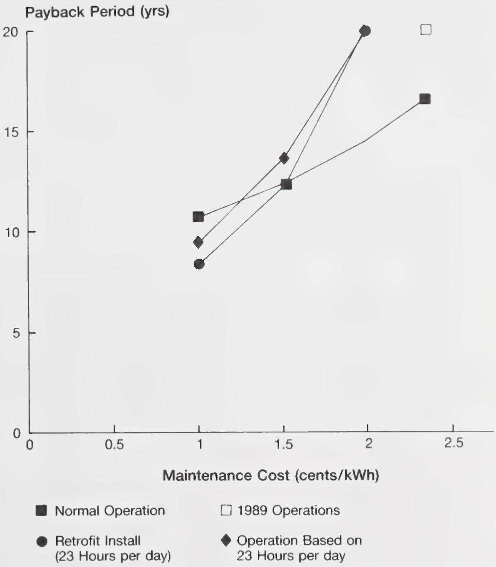


(Source: *Co-generation Demonstration: Commercial Buildings, Phase III Final Report*, Northwestern Utilities Limited, March 1990)

Cleaning by Page
Payback Analysis
With Power Factor Compensation



Cleaning by Page
Payback Analysis
Without Power Factor Compensation



(Source: *Co-generation Demonstration: Commercial Buildings, Phase III Final Report*, Northwestern Utilities Limited, March 1990)

Original Estimates versus Actual Data

	Original	Actual	% Better (Worse)
Gas Cost	$1.86/GJ	$1.85/GJ	0.5
Electricity Cost	$0.0518/kWh	$0.0467/kWh	(9.9)
Maintenance Cost	$0.0050/kWh	$0.0236/kWh	(372)
Thermal Efficiency	730 270 BTU/hr	759 779 BTU/hr	4
Overall Efficiency	91.5%	81.6%	(9.9)
Operating Hours	4 786 hours	1 961 hours	(144)
Gas Consumption	1.28 GJ/h	1.46 GJ/h	(13.8)
Capital Cost	$102 000	$166 300	(63)
Payback Period	4.6 years	20+ years	(335)

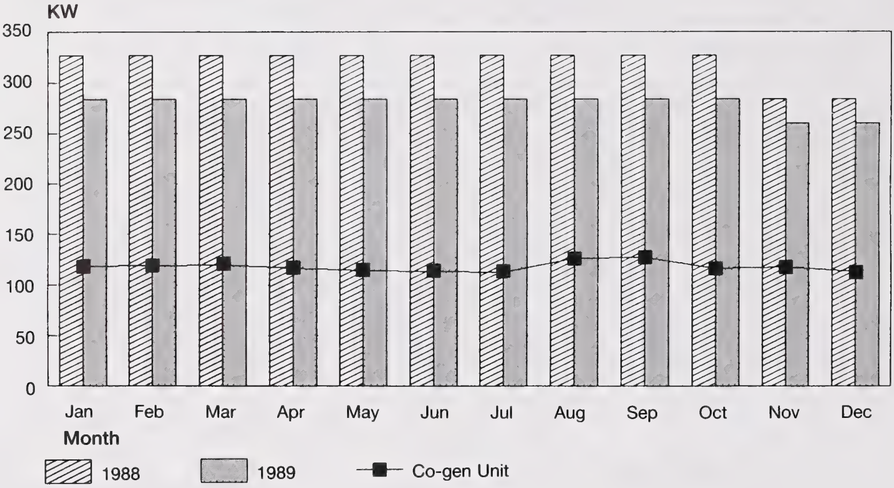
In addition, the hourly gas-consumption costs amounted to $2.69. The thermal savings, however, were $3 492 for the year, or $1.78 an hour, and hourly revenues from electricity generation were $5.03. The net gain for operating the co-generation unit for the first year was $1.58 an hour. Considering the total cost of $166 300 to purchase and install the unit, a payback period in excess of 20 years was calculated. Initially, it had been anticipated that a 4.6-year payback period was likely.

High maintenance costs were the major contributor to the unanticipated level of operating costs for this co-generator. This was attributed to persistent control problems that were not resolved until a manufacturer's representative was called in. The engine operated well.

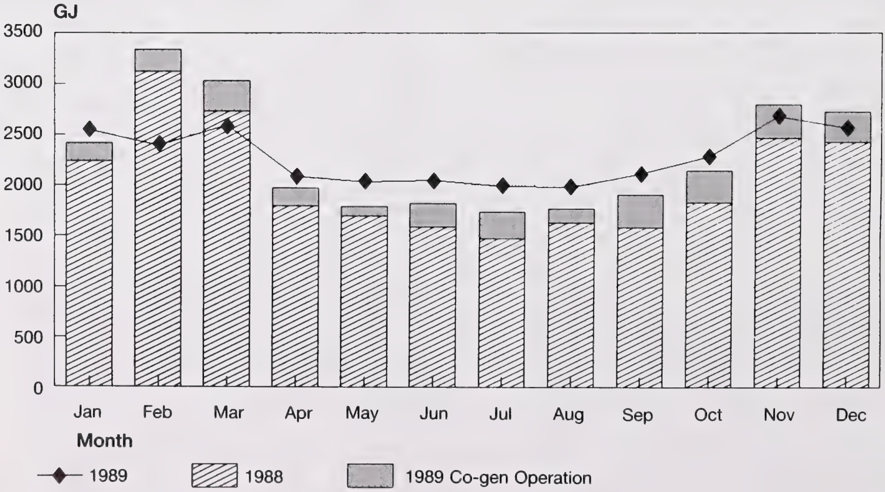
The laundry's demand for electricity from outside sources did not drop as low as was anticipated while the co-generator operated. This was attributed to the use of low-efficiency motors and electrical equipment throughout the plant. Given the structure of Edmonton Power's rate system, the installation of power factor compensation equipment should allow an appropriate reduction in both the demand for electricity and the electricity charges.

Calculations showed that if the co-generator could be operated 12 hours a day, as anticipated initally, and power factor compensation were provided, the payback period could be reduced to approximately 11 years. While this would be an improvement, it is still not economically attractive. Nonetheless, Northwestern Utilities will be monitoring the unit beyond the A/CERRF-funded study period and making changes to help reduce both the operating costs and the payback period.

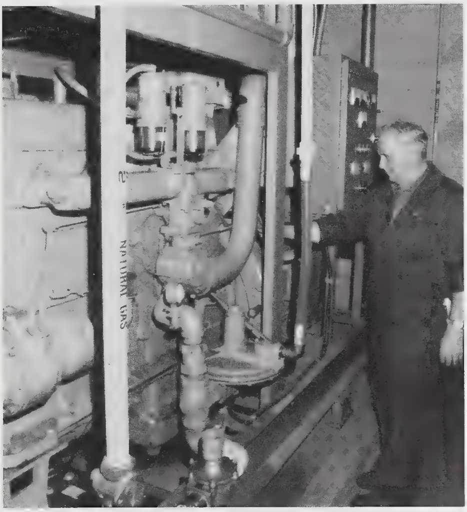
Cleaning by Page Electricity Demand



Cleaning by Page Gas Usage



(Source: *Co-generation Demonstration: Commercial Buildings, Phase III Final Report*, Northwestern Utilities Limited, March 1990)



115 kW co-generator installed at a Cleaning by Page laundry in Edmonton.
(Photo courtesy of Northwestern Utilities Limited)

Further Reading

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Stanley-Ekono. Edmonton District Heating Feasibility Study. Phase Two Financial Feasibility. 1980.

Vardabasso, M. and C.T. Grusendorf. 1986. Co-generation Assessment Study. First Phase Report. Southern Alberta Institute of Technology.

Contacts

Additional information about the co-generation assessment study is available from:

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Southern Alberta Institute of Technology
1301 - 16 Avenue N.W.
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For more information about the use of co-generators for peak demand shaving, contact:

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Edmonton, Alberta
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Telephone: (403) 421-4440

Additional details regarding the co-generation demonstration project in Edmonton are available from:

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Additional copies of this publication are available from:

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Other publications in this series that deal with energy conservation include:

A Practical Method for Defouling Heat Exchangers, 6 pages, March 1986.

Energy Management in Commercial Buildings, 8 pages, December 1986.

Control of Heat Loss Associated with Overhead Doors, 6 pages, January 1987.

Practical Methods to Seal and Insulate Residential Buildings, 9 pages, March 1987.

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Some Energy-Saving Measures for Commercial Buildings, 9 pages, January 1989.

The Feasibility of Energy-from-Waste Incineration in Alberta, 10 pages, April 1990.

Some Energy Conservation Concepts for Recreational Facilities, 10 pages, June 1990.

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